Neither crowding in nor out: Public direct investment mobilising private investment into renewable electricity projects

Matteo Deleidi[1], Mariana Mazzucato[2], Gregor Semieniuk[3]

Abstract

Rapid structural change towards a low-carbon energy supply requires significant additional investments into innovative but high-risk low-carbon technologies. Mobilising greater private investments requires applying the right policy instruments, but while fiscal measures and regulation have been well researched, systematic quantitative evidence about the effect of public direct investment is lacking. Absent empirical evidence, contradictory theoretical arguments claim that such public (co-)investments either ‘crowd out’ or ‘crowd in’ private investors. In this paper we show that the macroeconomic concept of crowding out/in is inapplicable to sectoral studies such as of renewable electricity. Instead, both neoclassical microeconomics and evolutionary economics suggest public direct investment to have a positive effect due to either externalities or market creation effects. We also provide the first quantitative estimate of the effect of public direct investment on private investment into renewable electricity technologies for 17 countries in the period 2004-2014. Using FGLS and static and dynamic GMM estimators, we find that public investments not only have a positive but also consistently the largest effect on private investment flows relative to feed-in tariffs, taxes and renewable portfolio standards in general, and for wind and solar technologies separately. Implications for policy aimed at accelerating the low-carbon transition are discussed.

[1] Department of Economics, University Roma Tre and Institute of Innovation and Public Purpose, UCL
[2] Institute of Innovation and Public Purpose, UCL
[3] Department of Economics, SOAS University of London, Institute of Innovation and Public Purpose, UCL, and Political Economy Research Institute & Department of Economics, University of Massachusetts Amherst
Corresponding Author: Gregor Semieniuk, SOAS University of London, Thornhaugh St, Russell Sq, London WC1H 0XG, UK; gs53@soas.ac.uk

JEL G3, H23, H54, O3, Q42, Q48, Q55

Keywords: public direct investment; crowding out; renewable electricity technology; innovation financing; externality; market creation

1. Introduction

Insufficient investment into low-carbon technologies is emerging as one of the key pivots in mitigating climate change. In the energy sector, models in the new IPCC 1.5°C report suggest aggregate annual energy supply investments may have to be 50% higher in 2016 to 2050 compared to current levels, to meet the Paris Agreement targets (IPCC, 2018, p. 18). In addition, the direction of investments has to radically shift towards low-carbon energy (across the energy supply, not just in power), with gross investments into low-carbon sources to overtake that into fossil fuels as soon as 2020 (McCollum et al., 2018 Fig.5). These developments require a large uptick in low-carbon energy supply investments (Semieniuk and Mazzucato, 2019). In addition, IPCC projections rely on optimistic forecasts about low future energy demand (Loftus et al., 2015; Semieniuk, 2018), so the investment estimates can be considered conservative.

In contrast with such projections, actual global investment into low-carbon energy supply has stayed roughly constant since 2011 (IEA, 2018) and investments into renewable electricity technologies (RETs), an important subset of low-carbon energy supply, have been stagnant since 2015 (UNEP and BNEF, 2019). It is widely recognised, first, that private funds must finance most of these investments and, second, that radical mitigation policies must be implemented to realise such a tremendous private investment upsurge, which implies a simultaneous redirection of private investments from high- to low-carbon technologies. The level or type of policy deployed so far has not achieved this. For instance, in spite of an increasing number of policy measures deployed, recent investments from private sources into RETs did not climb above pre-Great Recession levels of 2008 (Mazzucato and Semieniuk 2018). This raises a question about what type of policy had what effect in the past on private investment. If policy is to become more radical, it is important to understand what has worked so far.

The most widespread measures are price and quantity-based instruments, applicable to all investments in a certain technology, and more discretionary measures that often involve direct participation from public actors. There is general agreement among analysts that price-based mechanisms, such as feed-in tariffs, and quantity restrictions, such as renewable portfolio standards, are effective at mobilising private investments (Aldy et al., 2010). So are auctions (essentially an allocation mechanism for feed-in tariffs), although design details matter (Polzin et al., 2019). The theoretical justification for these price- and quantity-based interventions comes from microeconomics: they help internalise uncorrected externalities (Jaffe et al., 2005). Empirical evidence for the importance of such across-the-board measures is also abundant, though context and design matter. For feed-in tariffs and renewable portfolio standards, Ang, Röttgers and Burli (2017) find statistically significant positive effects on aggregate RET investments for 46 countries for 2000-2014; Polzin et al. (2015) find statistically significant positive effects of feed-in tariffs and codes and standards for 2003-2011 in the BNEF database (about 90 countries); Cárdenas Rodríguez et al. (2015) for 2000-2011, also in the BNEF database, find statistically significant positive effects of feed-in tariffs, but not quotas on private investments only; and in a recent review of 94 studies, Polzin et al. (2019) find that in most cases both feed-in tariffs and quotas are effective in increasing investment return while decreasing risk, thus effectively drawing in private finance.

Evidence is much less clear for discretionary measures and, in particular, public direct investment. Although evidence from interviews with investors and renewable energy developers suggests co-investment by public banks may be key to mobilising private investors (Geddes et al., 2018), and the private investment into high risk projects is positively correlated with co-investment from state-controlled actors (Mazzucato and Semieniuk, 2017), existing research has not systematically quantitatively examined the effect of public investments on private ones.

Cárdenas Rodríguez et al. (2015) find that when public actors participate in financing a project, the amount of private finance per project declines, which is unsurprising, but does not explain what happens to overall financing in a country or whether the project would have gone ahead without public participation. Polzin et al. (2015) only examine funds made available by the federal government to local governments. Ang, Röttgers and Burli (2017) only consider public R&D, which they report has little effect on aggregate investment, and the presence of state-owned enterprises, which has a positive effect in their sample. In their review study, Polzin et al. (2019) find only 14 out of their 94 studies looked at public direct investment and conclude there is "limited mixed evidence" (Table 2) for its effectiveness.

This is a worrying lack of systematic knowledge as official publications report public investment shares in renewable energy at around 15% (IRENA, 2018a). After cleaning the underlying microdata from Bloomberg New Energy Finance (BNEF) on which these estimates rely, Mazzucato and Semieniuk (2018) even find that as much as 40% of investment into RET supply assets has been financed by government agencies and state-controlled enterprises in recent years, which has accounted for all the growth in global utility scale investment post-Great Recession. Prag, Röttgers and Scherer (2018, Figure 5) confirm these high public shares even without accounting for state bank investment, which is underreported in the BNEF dataset they use. Given the prevalence of public direct investment, it is important to understand better its role in mobilising private investments.

However, in spite of the mostly anecdotal empirical evidence, opinions are very strong on the utility of direct public investment, largely on theoretical grounds, and they diverge. On the one hand, public investments are alleged to 'crowd out' private investors into low-carbon deployment that would have otherwise contributed their funds (Geddes et al., 2018). Public sector actors, in particular banks, can lend at lower interest rates than commercial banks, so if a developer has the option to choose between two lenders, they naturally prefer the one with the lower rate. Similarly, a state-owned utility can invest with a lower expected internal rate of return, going for projects before any profit-seeking private actor would. Since state investments may not work according to price signals but by the directive of a government, they can cause misallocation of resources and inefficiencies. Thus, the Climate Policy Initiative cautions that when state banks invest in renewables, there is "a real risk that without proper consideration of local circumstances they could hinder the involvement of private actors, potentially competing (crowding out) private sector lending or investment" (Buchner et al., 2013, p. 18).

Similar caveats about public involvement are expressed by other grey literature studies (OECD 2017, p. 281) and also some academic studies that caution against ‘inefficiencies’ from public misallocation of funds (reviewed in Geddes et al., 2018). On the other hand, many observers claim the exact opposite: that public direct investments will ‘crowd in’ private actors and are therefore effective at scaling up private investments. The debate about public direct investment is effectively structured around those two poles. With both crowding out and crowding in sometimes mentioned in the same publication (Buchner et al., 2013; IEA, 2017), the theoretical and empirical status of direct public investment as a policy tool is in need of clarification.

In this paper, we review the theoretical rationale for public direct investment in low-carbon technology and provide the first quantitative evidence for the effectiveness of direct public investments in increasing private investments into RET. First, we analyse the theoretical foundations for crowding out and crowding in as they pertain to RET investments. We review the origin of both terms and then discuss their applicability to the issue of RET to better understand the grounds on which either of these terms can be invoked, drawing both on neoclassical economics and evolutionary theories of innovation. Then, we estimate empirically the importance of direct public investments vis-à-vis other policy instruments based on a unique dataset of public and private investment flows. We use the new dataset of annual public and private investments built by Mazzucato and Semieniuk (2018) by cleaning ownership information in BNEF microdata to calculate national annual public and private investment flows, and complement them with annual feed-in tariff, emissions standard and carbon tax policy data for 17 countries over the 11-year period 2004-2014. For this panel with 187 observations, we estimate the effects of various policy measures using FGLS and GMM estimators to compare the magnitudes of the effects on private RET investments. Our analysis considers both total RET investments and the key technologies, solar and wind, separately.

Our theory review shows that the crowding out/in concepts are only applicable in macroeconomic theory. But the relevant level of analysis for individual industries, e.g. RET, is microeconomic: invoking arguments either about crowding out or in are inconsistent with the microeconomic narrative of market failures, which is also the criterion used to assess the effectiveness of subsidies and portfolio standards. According to microeconomics, public investments in markets with failures can help correct these failures and thus mobilise private financial flows. Similarly, evolutionary economic theories about innovation and diffusion are keenly aware of the market-creating role of government finance, and so we argue that there is little theoretical ground on which to disparage government financing a priori.

Our empirical study is the first to compare the magnitude of impacts of public direct investment with other policies on mobilising private investments. We find that, in our dataset, increases in public direct investments have the largest impact on private investments, while subsidies and taxes have smaller positive impacts, and the direction of impact of emissions standards is ambiguous and its magnitude small. These results are also confirmed when investment in solar and wind technologies is considered in different models. In Section 2, we review the theoretical rationale of crowding in and out and derive hypotheses for the empirical analysis. In Section 3, we present data and methods used to estimate findings presented in Section 4. Section 5 concludes with a discussion of the ramifications of these results for RET policies and to what extent they may carry over to other industries where certain low-carbon technologies are just now in the risky deployment phase.

2. Neither crowding out nor crowding in

With ambiguous and overall little systematic evidence on the effect of public direct investments into RET, theoretical arguments loom large. Public participation is either disparaged by pointing to 'crowding out' or lauded by referring to their 'crowding in' effects. Either of these terms is mentioned often only once in a whole paper and without citation, suggesting the concept is common sense. In this form, notions of crowding out or crowding in propagate into the literature and pertinent policy discussions. Here we show that both of these terms apply to *macroeconomics* only. For sectoral studies like energy, a better concept is 'mobilising' private finance.

2.1. Crowding out

Crowding out refers to "all the things which can go wrong when debt-financed fiscal policy is used to affect [aggregate] output" (Blanchard, 2008). Its magnitude and importance is a matter of longstanding debate in macroeconomics. Its typical channel of operation is to increase the interest rate, making it more costly for private undertakings to be financed and hence curtailing investment and thereby aggregate expenditure and output. What is important to the discussion here is that it is a *macroeconomic* concept, and therefore applies when the entire economy with its interlinkages and the entire government budget is concerned (see the appendix for a short overview over the term's history in macroeconomics). Therefore it is surprising that 'crowding out' also appears in energy economic research concerning only a subset of the economy. Nemet and Kammen (2007) ask whether increased government energy R&D may have crowded out private energy R&D and reduced public R&D in other sectors “by limiting these other sectors’ access to funding and scientific personnel” (p. 753). They find no such effects. These results are confirmed by Popp and Newell (2012), who use patterns in patenting to check effects of R&D re-allocations and also speak of crowding out. However, it is important to notice that these discussions are *microeconomic*; that is, they refer to sectoral and functional (i.e only R&D spending), rather than aggregate or macroeconomic, problems. And indeed, apart from the idea of crowding out, both Nemet and Kammen, and Popp and Newell, consistently underpin their research with neoclassical microeconomic theory.

From this theoretical point of view, the relevant question is whether an increase in public energy R&D increases social welfare. Since the ‘market failure’ of potential inappropriability of research outcomes, or knowledge spillovers, leads to private underinvestment, government R&D is seen to correct the market failure and increase welfare. In this setting, crowding out is inapplicable because it’s unclear whether government R&D funds are raised via debt or whether they are reallocated from other (less efficient) non-R&D activities, so nothing can be said about the effect on interest rates or of taking away resources. Moreover, neoclassical microeconomic theory of the second best has long established that whenever one general equilibrium assumption is violated, Pareto improvements typically require the introduction of additional ‘imperfections’ in the form of government intervention (Lipsey and Lancaster, 1956). The same holds in general equilibrium in the presence of information asymmetries (Greenwald and Stiglitz, 1986).

In other words, applying the crowding out concept to sectoral spending makes little sense in innovative activities where a knowledge market failure is present, in addition to the environmental externality of carbon emissions (Jaffe et al., 2005). But even between-sector crowding out, when only considering R&D activities or only other functional categories of government expenditure, has little theoretical traction because it remains unclear whether additional energy R&D raises interest rates (or the wages of scientists or 'innovators', whose jobs may be more or less substitutable with other occupations). It is no coincidence that the economic literature discussing industrial policy and boosting sectors from a neoclassical point of view does not mention crowding out (see, for example, Suzumura (1997) on Japan's industrial policy success). Briefly, the concept of crowding does not pertain to sectoral or functional subsets of government spending. It only applies when all government expenditures are considered, i.e. when studying the aggregate economy.[4]

As a consequence, invoking crowding out in RET demonstration and deployment finance, where innovative enterprises and projects do not get sufficiently funded due to information asymmetries (Hall and Lerner, 2010), has little theoretical grounding either. Public direct investments can help correct market failures, improve efficiency, and raise productivity and output. What is left is the trivial idea that when one entity, say Bank A, lends to Project P, then Bank B cannot lend to Project P anymore. Bank A has crowded out (or substituted for, replaced, blocked or outcompeted) Bank B.

[4] The concept is well understood whenever it is used in neoclassical general equilibrium models of renewable energy investment that consider the entire economy, where it must be counterbalanced against the efficiency improvements from correcting market failures, e.g. in IRENA (2017). Moreover, recent evidence shows government investment can be particularly effective, since the public investment multiplier is greater than the tax and incentives multiplier (Deleidi and Mazzucato 2018).

But whether these banks are privately or publicly owned makes little difference and effects on economy-wide interest rates play no role whatsoever.

The theoretically deep insight of crowding out in macroeconomics has no comparable place in sectoral microeconomic studies.[5] At the microeconomic level, public investment only becomes *inefficient* (but not crowding out) in the neoclassical economic sense when *all* market failures are removed, and public banks lend at concessionary rates or state-owned enterprises invest with below-market internal rates of return and finance an inefficiently large number of projects.[6] In this theoretical situation of 'perfect competition', investments are best made by private actors following price signals that maximise welfare. Due to the continued uncorrected environmental externality from climate-changing greenhouse gas emissions, it is unlikely that even an approximation to this 'first best' situation is the case in RET project finance. Therefore, claims that government investments into RET deployment can displace putative private investment (Azhgaliyeva et al., 2018; Buchner et al., 2013; Bürer and Wüstenhagen, 2009; Liu, 2016) or could even lower the overall amount of RET deployment investment because of market-distorting actions (Torres and Zeidan 2016, OECD 2017; Lo 2014), all of which invoke crowding out, are unconvincing. These analyses would need to move to the macroeconomic level to examine how these public investments fit into the economywide spending flows.[7]

[5] Yet it is used in a variety of fields, e.g. wind electricity crowding out hydro power (Førsund et al., 2008), wind installations crowding out solar photovoltaic installations (Lo, 2014) or, in a different context, government grants to charitable institutions crowding out private donations (Andreoni and Payne, 2011). The lax usage of this term from macroeconomics was perhaps encouraged by Schumpeter (1954, p. 642, fn 73) who at one point used crowding out to describe firms exiting a competitive market.

[6] For a discussion of the problem of 'government failure' see Mazzucato and Semieniuk (2017).

[7] The same critique also applies to the crowding-out caveats to 'additionality' of government investments that are often invoked in discussion of the effectiveness of government support to R&D (Marino et al., 2016) and also in the context of the Kyoto protocol's Clean Development Mechanism (Shrestha and Timilsina, 2002).

2.2. Mobilising, not crowding in

Crowding in, a term used to describe the *macroeconomic* multiplier effect (see appendix), too, has found its way into publications that engage in microeconomic reasoning around renewable energy investments by public entities. Thus it is argued that a Green Investment Bank could 'crowd in' private clean energy sector investments (Jaiswal et al., 2016) or that the UK's Green Investment Bank has crowded in private investors to the tune of £2.2 billion on projects where it has itself invested £1.3 billion (Campiglio, 2016). Without a macroeconomic context, these statements are imprecise as the public investment here does not lead to additional spending rounds by private actors who get the receipts of *additional* (debt financed) public spending in the aggregate. What these authors seek to describe instead is that public entities take the lead in specific investment projects and bring on board private actors that would not otherwise have invested in this specific project (Mazzucato 2016). Naturally, terms can be used by everyone as they see fit, yet the historical definition of crowding out and in as precise theoretical macroeconomic concepts can mislead readers. This is especially true of the term crowding out due to its close association with a negative effect of government activity. Usage of crowding in also acknowledges crowding out by suggesting the opposite can happen. Yet in a microeconomic analysis of one sector with informed government investment that seeks to correct one or more market failures, there is only an upside, no downside.[8] A better term to describe the government function in this case is *mobilising* private finance.

[8] See Foley, Rezai and Taylor (2013) for pointing out the oversight in the debate on climate mitigation, focused as it is on an intergenerational trade-off, that there is only an upside to correcting the negative externality associated with greenhouse gas emissions.

It is important to realise that market failures in microeconomics only arise from the neoclassical point of view of actual market conditions as ‘imperfections’ and ‘distortions’ of a perfect economy in the neoclassical sense: perfect information, no transaction costs and all interactions mediated by a market in goods over which property rights are completely defined, and about whose evolution, if multiple periods are modelled at all, agents also possess perfect foresight (Shaikh 2016). These assumption imply a static structure of the economy (Heim and Mirowski, 1987). Evolutionary theorists, starting from a more dynamic view of an economy with innovation and structural change, have long developed an alternative analysis of technological change and market behaviour, which points to a key role for institutions, including government, in nurturing and sustaining innovation beyond the market failure penumbra (Freeman, 1995; Freeman and Perez, 1988; Nelson, 1995; Perez, 2002, 1983). Thus, market failure theory must argue that investments into novel technologies are underfunded simply because the return isn’t high enough or, what amounts to the same thing, because lenders lack information on project credit-worthiness, which they could get if the rate of return were high enough to justify gathering it. Innovation investments are no different qualitatively from those into proven technologies, and externalities simply distort the structure of the economy.

Evolutionary theorising recognises that investment in innovative technologies requires facing intrinsic uncertainty over a long time horizon, which makes them qualitatively different from fully proven technologies, but if realised, they can change the economic structure. Here, governments, with their unique ability to take on risks, can play an entrepreneurial role unlike any other economic actor (Block and Keller, 2011; Foray et al., 2012; Mazzucato, 2018 [2013]). This is true both for research and development of wholly new products and sectors (such as for space flight, financed by NASA, or the Internet, financed by the US military), and demonstration and early deployment periods where indivisible expenses become very large, a problem particularly acute in expensive plant and infrastructure technologies, such as smart grids and generation of renewable electricity (Semieniuk and Mazzucato, 2019). The energy transition provides an important instance where such evolutionary dynamics dominate (Grubb et al., 2014; Hall et al., 2015). The key role of government for shifting the structure of the economy towards new products has also been documented in studies of the Asian economies that managed a quick structural change towards manufacturing industries and economic development post-1960 (Amsden, 1989; Wade, 1990).

Seen through an innovation perspective, direct investment by state-controlled actors has also been recognised as being key for RET deployment (Anadón, 2012; Mazzucato and Semieniuk, 2017; Nemet et al., 2018; Polzin, 2017). An additional challenge in the power sector is the particularly high capital intensity of RET assets and the large scale of individual projects (Lester, 2014; Tietjen et al., 2016), which must compete not by putting a new product on the market, but by supplying the same product already produced by fossil- powered incumbents (all produce electricity), which have until recently been cheaper. In other words, competition is only on prices and private finance may be insufficient all the way until renewables are the cheapest option (Egli et al., 2018).[9]

[9] 'Capital-intensive' here refers to the large scale of a single investment, e.g. individual demonstration projects can quickly cost upwards of US$1 billion; it also means the share of upfront capital expenditure relative to lifetime operating and maintenance costs is large.

With crowding out and in arguments inapplicable, and both neoclassical market failure and evolutionary entrepreneurial state theories arguing that government investment in RETs should help mobilise private investment, we hypothesise first that **direct government or state-controlled enterprise investment into RET deployment should have a positive effect on private investments into RETs**. We hypothesise secondly that **the discretionary government investment effect is large relative to that of other policy measures**, because with inherent uncertainties, long lead-times and lumpy capital expenditures, evolutionary theory suggests that public (co-)investments may influence private collaboration that may be more suited to uncertain yet costly innovation investments than taxes or even more passive standards, which work via penalties, not rewards. This is exactly the situation that applied to many RET investments over the period of analysis: 2004-2014.

3. Data and methodology

3.1. Data

Using data provided by BNEF, Organisation for Economic Co-operation and Development (OECD) statistics and the World Bank, we conduct an econometric analysis on selected OECD countries for the period 2004-2014.[10] Data on RET investments are taken from the BNEF microlevel dataset modified by Mazzucato and Semieniuk (2018), which we aggregate to provide annual public and private

[10] The analysis is carried out on the following countries: Australia, Brazil, Canada, China, Denmark, France, Germany, India, Italy, Japan, Korea, Norway, Portugal, Spain, Sweden, United Kingdom and United States.

investment levels on RET, including biomass, geothermal, marine, small hydro, solar and wind technologies; it also includes biofuel investment for transport. As described in detail in Mazzucato and Semieniuk (2018), the individual projects can have several (public and private) investors, which we distinguish, so the resulting public and private measures partition the separate public and private contributions also to projects with mixed investors. There is no overlap. This allows us to interpret the effect of public on pricate finance, which we explain in our model below, as both mobilisation of private investors on the same project as that in which public investment occured, and on subsequent projects. The bulk of investments flows towards onshore wind and solar photovoltaics. The World Bank dataset provides data on annual amount of energy per capita used. The OECD dataset provides annual data on other policy instruments implemented by national governments, including market-based instruments (e.g. taxes and incentives) and non-market instruments (command and control regulations). The list of variables is composed of the diesel tax rate, the emissions standard, and feed-in tariffs for wind and photovoltaic energy. To take into consideration the level of economic activity, we use the level of GDP at constant prices, while the interest rate on private investment is captured by the real lending rate applied by banks, both also from the OECD. Finally, we convert all variables to US dollars by using the exchange rate provided by the OECD data set and we consider all variables in real terms. All used variables are described in Table 1

In our analysis, the effectiveness of policies is measured by coefficients associated with $\boldsymbol{INV\_pu}$, $\boldsymbol{FIT\_ws}$, $\boldsymbol{TAX\_dies}$ and $\boldsymbol{EPS\_stan}$. The overall investment climate is captured by the effect of interest rates ($\boldsymbol{INT\_lend}$) on the level of private investments. Here, the basic idea is that monetary policy affects lending rates (Deleidi, 2018; Deleidi and Mazzucato, 2018a), which, according to the standard perspective, should affect the level of private investment. GDP controls for the size of the economy, while energy use per capita controls for the differential energy intensities. Additionally, we consider $\boldsymbol{INV\_pu}$, $\boldsymbol{INV\_pr}$ and $\boldsymbol{FIT\_ws}$ broken down by technologies, namely solar and wind ($\boldsymbol{INV\_pu\_s}$, $\boldsymbol{INV\_pu\_w}$, $\boldsymbol{INV\_pr\_s}$, $\boldsymbol{INV\_pr\_w}$, $\boldsymbol{FIT\_s}$ and $\boldsymbol{FIT\_w}$). Table 2 shows summary statistics of all variables converted to their 2011 USD equivalents. Country-level private investment fluctuates widely, but all countries had positive investments in every year, both public and private.

TABLE 1 ABOUT HERE

TABLE 2 ABOUT HERE

3.2. Methodology

We implement a static and dynamic panel data methodology on the variables in Table 1 to explore the effects of alternative environmental policy interventions on private investments in RETs. Specifically, we assess the effect of alternative types of fiscal and regulatory policies in leveraging private investment in renewable energy projects, controlling for economic activity, energy use and monetary policy.

As a first step, to manage data accurately, we apply the redundant fixed effects (FEs) test which shows that cross-section FEs are not redundant (all tests in Table 3). This result allows us to conclude that unobserved heterogeneity exists across countries, which is captured by the constant of the model. As a second step, the cross-section dependence test and the panel heteroskedasticity test are performed to examine both the presence of cross-sectional dependence as well as whether residuals are homoskedastic. The results of the aforementioned tests suggest that a cross-section dependence in the residuals, as well as a panel cross-section heteroskedasticity, exist. On the contrary, there is no panel period heteroskedasticity. In a third step, we estimate a feasible generalised least squares (FGLS) estimator with cross-section weights and white cross-section standard errors for robustness with respect to heteroskedasticity and cross-sectional dependence (Wooldridge 2010).[11] Additionally, we are agnostic on (non-)stationarity with the panel T=11 years being smaller than N=17 countries (Baltagi, 2013; Kao and Baltagi, 2001).

TABLE 3 ABOUT HERE

By using an FE model estimated by means of an FGLS estimator, the model assumes the following form (1):

$$
\begin{aligned}
INV\_pr_{i,t} = a &+ \beta_{2i} INV\_pu_{i,t} + \beta_{3i} TAX\_dies_{i,t} + \beta_{4i} FIT\_ws_{i,t} \\
&+ \beta_{5i} EPS\_stan_{i,t} + \beta_{6i} GDP\_real_{i,t} + \beta_{7i} INT\_lend_{i,t} \\
&+ \beta_{8i} ENE\_use_{i,t} + \varepsilon_{i,t}
\end{aligned} \tag{1}
$$

where i represents the cross-sectional component and t the time component.

[11] All estimated models (from 1 to 6) contain robust coefficients since estimates control both for heteroskedasticity and cross-sectional dependence.

Dynamic panel estimation results from introducing the lagged dependent variable as an independent one (Judson and Owen, 1999), as shown in equation (2):

$$
\begin{aligned}
INV\_pr_{i,t} = a &+ \beta_{1i} INV\_pr_{i,t-1} + \beta_{2i} INV\_pu_{i,t} + \beta_{3i} TAX\_dies_{i,t} \\
&+ \beta_{4i} FIT\_ws_{i,t} + \beta_{5i} EPS\_stan_{i,t} + \beta_{6i} GDP\_real_{i,t} \\
&+ \beta_{7i} INT\_lend_{i,t} + \beta_{8i} ENE\_use_{i,t} + \varepsilon_{i,t}
\end{aligned}
\qquad (2)
$$

To get a robust picture of the different effects of alternative environmental policy interventions, we will also estimate the model with a generalised method of moments (GMM) estimator for panel data (Arellano and Bond, 1991; Arellano and Bover, 1995; Blundell and Bond, 1998). Such estimators allow controlling for endogeneity between the dependent and explanatory variables. In particular, endogeneity issues are solved by instrumenting regressors with a lagged level of values of explanatory variables. In general, a valid instrument must satisfy two conditions: (i) to be correlated with the regressor; but (ii) non-correlated with the error. Although we do test the validity of the instrument, it is clear that lagged values can be considered weakly exogenous, i.e. they are uncorrelated with the error at time t (Cameron and Trivedi, 2005, p. 749).[12] Following procedures in Cameron and Trivedi (2005), we estimate four different GMM models. The first one is a static GMM model (Kapoor et al., 2007; Lee and Liu, 2010; Lin and Lee, 2010; Liu et al., 2010), while the second one is an FE dynamic GMM model with a lagged dependent variable (Han and Phillips, 2010; Kapoor et al., 2007; Lee and Yu, 2014). Additionally, first-differenced GMM (Arellano & Bond 1991) and system GMM (Arellano & Bover 1995; Blundell &

[12] Starting from the initial model summarised in equation (1), in order to test the goodness of our instrument, we estimate: (i) the correlation between instruments and regressors; and (ii) the correlation between the instrument and the error term. Findings are available upon request and show that instruments are valid since they are strongly correlated with regressors, but not with the current period error.

Bond 1998) estimators are implemented for the dynamic panel. The former is a first-differences model which produces consistent estimates that are also asymptotically efficient in the presence of heteroskedasticity. The latter, which also requires weakly exogenous instruments, is based on a transformation defined as orthogonal deviation since transformed errors assume a unit variance and are uncorrelated.[13] Within these models, we verify the validity of the instruments by using the Sargan-Hansen test (also called J-statistic) for testing over-identifying restrictions.[14] In particular, we test the orthogonality between instruments and residuals or, in other words, the exogeneity of selected instruments. In our models, instruments are the one-year lagged values of endogenous variables. In the case of the Arellano-Bond estimator, we assess the presence of serial correlation by means of the Arellano-Bond serial correlation test.

To analyse public direct investment, in the next section, we present the results of six models which use: (i) an FGLS on static panel with FE (Model 1); (ii) an FGLS on a dynamic panel with FE (Model 2); (iii) a GMM estimator on a static model with FE (Model 3); (iv) a GMM estimator on a dynamic model with FE (Model 4); (v) a system GMM estimator (Model 5); and (vi) a first-differenced GMM estimator (Model 6). Additionally, all models are re-estimated only for two specific types of technologies, namely wind and solar, using the additional time series for investment and feed-in tariffs for these technologies.

[13] In particular, the Arellano-Bover transformation, based on the forward orthogonal deviations, subtracts from the current data values the average of future observation for each observation.

[14] The over-identifying restrictions test was developed by Hansen (1982) as an extension of a test proposed by Sargan (1958) for linear instrumental variables.

Since all variables in equation 1 and 2 are measured in different units, they are standardised, enabling us to compare the coefficients estimated.[15] The endogenous variable $INV\_pr_{i,t}$ is not standardised, but is considered in logarithmic form. This allows us to interpret the estimated coefficients as a percentage change in the level of private investment after one standard deviation increase in the level of selected exogenous variables.

4. Findings

Findings for all RET investments are summarised in Table 4 and show a clear picture of the effect of policies on the volume of private investment in RETs across all six models. Public direct investments in RET projects have a consistently positive and statistically significant effect on private investment flows in our sample. The coefficient is also consistently larger than those of other policies and, since the standardised coefficients can be directly compared, these results suggest increases in public direct investments are the most influential policy tool to increase private RET investment. These results are confirmed both for solar and wind RET considered separately (Tables 5 and 6). These empirical results confirm both hypotheses derived from the theoretical literature on how public direct investments mobilise private investment flows: that they have a positive effect on private investments into RETs both in the same project (Geddes et al., 2018) and subsequent projects via demonstration (Nemet et al., 2018) and learning and scale

[15] The standard on emissions (EPS_stan) is measured through an ordinal variable, which is not standardised.

effects (Semieniuk and Mazzucato, 2019). The results also show that their effect is particularly large relative to that of other policy measures.

In more detail, Models 1 and 2, with an FGLS estimator, show that a one standard deviation increase in the level of public direct investment leads to an expansion in private investment of about 20%.[16] When we look at the effect of other policy tools, we find that an increase in taxes on hydrocarbons and the feed-in tariff generates a positive effect on private investment in renewables, that is lower than the increase generated by INV_pu. Differently from Model 1, in Model 2 a dynamic panel is estimated by introducing lagged value in private investments $INV\_pr_{i,t-1}$. The preliminary findings estimated with a FGLS in Models 1 and 2 are confirmed in the remaining models (3 to 6), whose coefficients are estimated by means of a GMM estimator: an increase in public direct investment INV_pu produces the largest positive effect on INV_pr. One standard deviation increase in public investment in renewables leads to a rise in private investment of: 19% in Model 3, 28% in Models 4 and 5, and 24% in Model 6.

Feed-in tariffs (FIT_ws) positively influence private investment in renewables too, but the effect is consistently lower than that produced by direct public investment. In Model 6, this effect is statistically insignificant. In our models we have also introduced the TAX_dies as a proxy of a carbon tax. A tax rise for hydrocarbons should lower profits in fossil energy investments and induce market operators to shift toward the now relatively more profitable renewables technology. Here, our findings suggest that TAX_dies is the fiscal policy with the lowest effect on INV_pr. Significant

[16] To have a percent variation, multiply the coefficient by 100.

positive coefficients close to 10% are found from Models 1 to 3. On the contrary, non-significant coefficients are found in Models 4 to 6. Regulatory policies such as emissions standards (EPS_stan) do not create any positive effect on private green investment. Such a puzzling result could be explained by a statistical problem related to the measurement of this variable, which assumes values from 1 to 6, but it also confirms earlier ambiguous or even negative results for regulatory measures from other studies (Cárdenas Rodríguez et al., 2015; Polzin et al., 2015) and this merits further study.

For our control variables, results show that the general level of economic activity (GDP_real) has a positive effect on private investment in Models 1, 3 and 6, whereas energy per capita use (ENE_use) does not significantly affect the volume of INV_pr. This suggests that a high energy intensity does not matter for the adoption of electricity from renewables, but findings may also be influenced by the stagnat energy per capita in several of the countries-years in the sample. Regarding the effect of monetary policy and in particular the interest rate INT_lend, we can affirm that this does not affect the level of private renewable investment: all coefficients associated to INT_lend and estimated for all models are non-significant. This confirms the hypothesis of the lack of impact of interest rate changes on the level of private investment at the macro level (Deleidi, 2018; Garegnani, 2015) for the energy sector. Our findings are in line with the studies claiming that business investments are insensitive to changes in the rate of interest and that monetary policy has a scarce effect on investment, see among others Chirinko (1993), Bernanke and Gertler (1995), Deleidi and Mazzucato (Deleidi and Mazzucato, 2018a, 2018b) and Deleidi (2018). On the contrary, a recent paper has shown that a certain degree of influence of interest rate on the level of renewable energy investment exists due to its higher capital intensity than competing fossil fuels and thus lower competitiveness at higher interest rates (Schmidt et al., 2019). It must be kept in mind that for the most part of the dataset, interest rates were fairly low and unvarying.[17]

The main results carry over both to solar and wind investments. In Table 5, the determinants of private investment in solar are analysed (INV_pr_s). Specifically, results show that public direct investment in solar (INV_pu_s) generates a positive and slightly larger effect on private investment than a solar-specific feed-in tariff (FIT_s). These results are confirmed in all selected models displayed in Table 4 (*1*_s *to 6*_s). Table 6 shows that for wind investments, again, public direct investment has a slightly larger positive effect than a feed-in tariff for wind (FIT_w) in all models (1_w to 6_w). The coefficients for public direct investment and feed-in tariffs are much larger for solar than wind. This may be partly due to larger variability in investments in solar in our sample, which started when solar investments were negligible and ended when they attracted the biggest share of all RET investments.

The Durbin-Watson (DW) tests reported in Tables 3, 4 and 5 confirm the adequacy of the introduction of lagged value of dependent variables $INV\_pr_{i,t-1}$ as this reduces autocorrelation by making the value of DW test closer to two. Furthermore, the J-statistic and its probability value, estimated for Models 3 to 6 (in Tables 3, 4 and 5), suggest that over-identifying restrictions are valid and selected instruments are exogenous. Furthermore, as depicted in Table 6 and in line with Arellano and Bond

[17] GMM models are also estimated by using instruments which are two-year lagged values of endogenous variables. Findings are robust to different model specifications, confirming that public investment in renewables generates the largest positive effect on private investment. Estimations are available upon request.

(1991) and Roodman (2009), the Arellano-Bond serial correlation test estimated for Model 6 shows that there is serial correlation at lag 1, but none at lag 2. This result is also confirmed for solar and wind RETs (see Table 6).

For our dataset our key findings produce a clear picture across models that can be summarised as follows: (i) public direct investment into RET has a positive effect on private investment; (ii) its effect is large relative to other polices, such as taxes, feed-in tariff and regulation; and (iii) these results hold for both the aggregate RET and the wind and solar subsets.

TABLE 4 ABOUT HERE

TABLE 5 ABOUT HERE

TABLE 6 ABOUT HERE

TABLE 7 ABOUT HERE

5. Conclusions and policy implications

In this paper we have investigated the effect of public direct investment on private investment into renewable electricity generation both theoretically and empirically. We have reviewed arguments against public investments and found them theoretically misplaced, in particular the idea of crowding out. This is a macroeconomic concept, while the problem of RET investments takes place at a microeconomic, sectoral level. Here, both market failure and evolutionary theories (but not the equally macroeconomic idea of crowding in) suggest that public direct investment has a positive effect on private investments, and that this effect should be large in innovative, high-risk technologies, of which RET were one example in the early 21st century. Taking these hypotheses as a starting point for our empirical analysis, we have estimated this effect for 17 countries over 11 years, 2004-2014, using novel data on the sources of investment that build on BNEF data, and contrasted it with the effects of feed-in tariffs, taxes and emissions standards on investment. Using FGLS and static and dynamic GMM estimators in a total of six models, we find that public investment, along with feed-in tariffs, is the only policy that has a consistently statistically significantly positive effect on the level of private investment. Moreover, the effect is consistently the largest in the sense that one standard deviation change in the regressor has the largest effect on the dependent variable. These findings are also confirmed when total investment (public and private) and feed-in tariffs are broken down by considering different technologies, namely wind and solar RET.

These results are new evidence for the key role that discretionary public investments directly into RET projects have played in the expansion of a low-carbon energy supply to date. The envisaged radical ramp-up of private investments into the energy supply is therefore likely to benefit from additional public (co-)investments. This study could not distinguish the modes in which public funds were flowing towards renewable power projects (e.g. whether via loan or equity) and there are important non-monetary aspects of public participation in investment projects that our quantitative analysis cannot register (Geddes et al., 2018; Polzin, 2017). Nevertheless, this first systematic quantitative evidence suggests that on average direct public participation is effective at mobilising private funds. Of course, discretionary public activity targeted at individual projects also requires more capacity and understanding of the market than simply giving subsidies to every project or imposing an economywide standard (which also requires capacity for enforcement). Therefore, the effectiveness of this policy instrument has to be seen also in the context of the capacity to deploy it. While many governments lack resources (Mazzucato et al., 2018), recent policy discussions about the role of state development banks are an encouraging sign of capacity-building (Mazzucato and MacFarlane, 2017).

These results also lend support for both the predictions of the neoclassical theory of market failure and of evolutionary theory of market creation. Most of the investments under consideration took place under conditions where renewable electricity was not yet competitive on prices with fossil fuels and could be considered an innovative technology, so the evolutionary economic claim that direct government intervention is effective via creating and shaping the market for the new products through investments has considerable purchase in this dataset. Although RETs are now close to cost-competitiveness with fossil-fuelled electricity (IRENA, 2018b), and the innovation argument may be less strong for technologies such as wind, neoclassical market failure theory furthermore suggests that as long as the carbon externality is still present, upscaled public investment can be effective for upscaled private investment.

However, even with several RET now more mature, these results provide important new information for other technologies considered central to moving the economy onto a low-carbon path that are at present further away from commercial viability. For instance, most projections of climate change mitigation rely crucially on large-scale ‘negative emissions technologies’, none of which are operational at present (Anderson and Peters, 2016), and low-carbon steel still needs radical process innovations (Åhman et al., 2018; Cullen and Allwood, 2010), as do materials more generally (Chu et al., 2017). These industries exhibit similarities with RETs in that they require capital-intensive investments with long-term horizons. Learning the lesson from RETs for their fast demonstration and deployment, public direct investments alongside other policies should be considered as a key policy tool, including strategies for funding these government investments via participation in the future gains, e.g. via equity ownership (Mazzucato, 2018), and structuring co-investments in ways that prioritise the social goals (e.g. climate change mitigation) these investments ultimately serve (Bayliss and Van Waeyenberge, 2018).

Additional research on these topics could investigate in more detail the comparability of RETs with other sectors that require investment surges, and the way in which these policies that assume substantial state capacity to raise finance and assess projects are applicable to governments with highly constrained resources. A micro-level analysis of RET investments could furthermore distinguish to what extent public investments are flowing towards higher-risk projects and what are the rates of mobilising private finance conditional on such riskiness.

Acknowledgements

The authors would like to acknowledge discussions with Paolo Agnolucci, Nadia Ameli, Ourania Dimakou, Michael Grubb, Dirk Rottgers and Daniele Tori about various aspects relating to this paper, and valuable feedback on earlier versions from two anonymous referees. Thanks are due to Bloomberg New Energy Finance for sharing their asset finance data.

Funding

This work was supported by Innovate UK and Horizon 2020 DOLFINS Nr. 640772.

Appendix: 'Crowding Out' in Macroeconomics

"'Crowding out' refers to all the things which can go wrong when debt-financed fiscal policy is used to affect output," wrote Olivier Blanchard (2008) for the *New Palgrave Dictionary of Economics* at a time when Western economies still appeared greatly moderated. Due to its definition in terms of fiscal policy and the level of aggregate output, crowding out falls squarely into the realm of macroeconomics, which considers the aggregate economy. There, it has a long history. It appealed to economists as early as Adam Smith (Spencer and Yohe 1970) and Alfred Marshall (Groenewegen 2003). In their theoretical model of an economy Say's law holds, and prohibits the government from raising the level of output by raising demand. As all resources (including monetary funds that can be borrowed) are already being used, employing them on public works would relocate, not add, economic activity. On the contrary, such projects might interfere with the price allocation mechanism, induce inefficiencies and reduce productivity and output.

Crowding out came to prominence in the debate between John Maynard Keynes and officials at the British Treasury in 1929, notably Ralph Hawtrey.[18] The 'Treasury View' was that debt-financed government expenditure (e.g. government investments into energy supply) could hardly create employment as it would take away funds from private investors due to crowding out, even though the economy was far from full employment and utilisation of resources (Peden, 1984). While Keynes admitted that debt-financed government spending could diminish "investment in other directions" (Keynes, 1936, p. 119), he maintained that it would far from offset the multiplier effect (Kahn, 1931), whereby government spending and the resulting employment it creates stimulates several almost instantaneous rounds of spending, thus raising effective demand, investment and creating further employment. This multiplier effect, later referred to also as "crowding in" (Friedman, 1978), thus posited exactly the opposite effect of government expenditure, pitting two world views against each other.[19]

After economies had cooled down from war-time planning, multiplier-accelerator theory (and therefore the idea of crowding in) ruled under the Neoclassical Synthesis of Keynesian demand management in the US and elsewhere for a couple of decades. However, this type of Keynesian economics came under attack from Monetarist and then New Classical economics, whose ideas seemed to better explain the economic situation of the 1970s stagflation, and focussed on monetary, not fiscal, policy (Friedman, 1968, 1956; Sargent and Lucas, 1979). Under the influence of these theories, crowding out was once again in vogue and, during the

[18] For a debate about the importance of crowding out during Britain's Industrial Revolution, see Heim and Mirowski (1987).
[19] Friedman reports the term was introduced by a report of the US Congressional Budget Office in 1975, as a different name for the spending effects of the multiplier in less-than-full resource utilisation economies.

‘Great Moderation’, fiscal policy was relegated almost to oblivion with a focus on rule-based inflation targeting under the New Neoclassical Synthesis (Goodfriend and King, 1997). The 2009 ‘Great Recession’ ushered big government stimuli back in, often with a green component (Carley and Hyman, 2013; Mundaca and Richter, 2015; Robins et al., 2009). Afterwards, admissions from the IMF that debt-financed fiscal policy can be effective (crowd in), at least in times of incomplete resource utilisation, shifted the balance somewhat in favour of the effectiveness of fiscal policy (Blanchard, 2013; IMF, 2013), but the academic debate about the size of the multiplier and even whether fiscal contractions (i.e. austerity) might be expansionary continues (Alesina et al., 2018; Ramey, 2011).

With full resource utilisation, there are only so many resources to go around and ‘real crowding out’ will simply reallocate resources from other agents if the government purchases them by raising prices. To see why crowding out arguments can also hold without full resource utilisation, consider the ‘financial crowding out’ that came to prominence during the monetarist attack (Friedman 1978). Here, even without full resource utilisation, additional government borrowing increases the demand for money and hence interest rates. This renders borrowing for investment in the private sector less attractive. Dynamic effects can bring in additional negative effects: the stimulated economy that returns to full employment still carries a higher level of debt, higher interest rates and, therefore, lower investment over prolonged periods (Blanchard 2008). Finally, with perfectly foresighted households, any increase in government spending is said to lead to an equal decrease in spending and saving for future tax increases, leading to so-called Ricardian equivalence (Blanchard 2008).

References

Åhman, M., Olsson, O., Vogl, V., Björn Nyqvist, Maltais, A., Nilsson, L.J., Hallding, K., Skånberg, K., Nilsson, M., 2018. Hydrogen steelmaking for a low-carbon economy. SEI Work. Pap. 2018–07.

Aldy, J.E., Krupnick, A.J., Newell, R.G., Parry, I.W.H., Pizer, W.A., 2010. Designing Climate Mitigation Policy. J. Econ. Lit. 48, 903–934. https://doi.org/10.1257/jel.48.4.903

Alesina, A.F., Favero, C., Giavazzi, F., 2018. What do we know about the effects of austerity? NBER Work. Pap. Ser. 24246.

Amsden, A., 1989. Asia’s Next Giant: South Korea and Late Industrialization. Oxford University Press, New York and Oxford.

Anadón, L.D., 2012. Missions-oriented RD&D institutions in energy between 2000 and 2010: A comparative analysis of China, the United Kingdom, and the United States. Res. Policy 41, 1742–1756.

Anderson, K., Peters, G., 2016. The trouble with negative emissions. Science (80-.). 354, 182 LP – 183. https://doi.org/10.1126/science.aah4567

Andreoni, J., Payne, A.A., 2011. Is crowding out due entirely to fundraising? Evidence from a panel of charities. J. Public Econ. 95, 334–343. https://doi.org/10.1016/j.jpubeco.2010.11.011

Ang, G., Rottgers, D., Burli, P., 2017. The empirics of enabling investment and innovation in renewable energy. OECD Environ. Work. Pap. 123.

Arellano, M., Bond, S., 1991. Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. Rev. Econ. Stud.

58, 277–297. https://doi.org/10.2307/2297968

Arellano, M., Bover, O., 1995. Another look at the instrumental variable estimation of error-components models. J. Econom. 68, 29–51. https://doi.org/https://doi.org/10.1016/0304-4076(94)01642-D

Azhgaliyeva, D., Kapsaplyamova, Z., Low, L., 2018. Implications of Fiscal adn Financial Policies for Unlocking Green Finance and Green Investment. ADBI Work. Pap. Ser. Implic. 861.

Baltagi, B.H., 2013. Econometric Analysis of Panel Data, 5th ed. Wiley, Chicester.

Bayliss, K., Van Waeyenberge, E., 2018. Unpacking the Public Private Partnership Revival. J. Dev. Stud. 54, 577–593. https://doi.org/10.1080/00220388.2017.1303671

Bernanke, B.S., Gertler, M., 1995. Inside the Black Box: The Credit Channel of Monetary Policy Transmission. J. Econ. Perspect. 9, 27–48. https://doi.org/10.1257/jep.9.4.27

Blanchard, O., 2013. Growth Forecast Errors and Fiscal Multipliers; by Olivier Blanchard and Daniel Leigh; IMF Working Paper 13/01; January 1, 2013. IMF Work. Pap. 1–43. https://doi.org/10.1257/aer.103.3.117

Blanchard, O.J., 2008. Crowding Out, in: The New Palgrave Dictionary of Economics. Palgrave Macmillan UK, London, pp. 1–4. https://doi.org/10.1057/978-1-349-95121-5_647-2

Block, F., Keller, M.R., 2011. State of Innovation. Routledge, Oxford and New York.

Blundell, R., Bond, S., 1998. Initial conditions and moment restrictions in dynamic panel data models. J. Econom. 87.

Buchner, B., Hervé-Mignucci, M., Trabacchi, C., Wilkinson, J., Stadelmann, M., Boyd, R., Mazza, F., Micale, V., 2013. Global Landscape of Climate Finance

2013. Climate Policy Initiative.

Bürer, M.J., Wüstenhagen, R., 2009. Which renewable energy policy is a venture capitalist's best friend? Empirical evidence from a survey of international cleantech investors. Energy Policy 37, 4997–5006. https://doi.org/10.1016/j.enpol.2009.06.071

Cameron, A.C., Trivedi, P.K., 2005. Microeconometrics: Methods and Applications. Cambridge University Press, Cambridge. https://doi.org/DOI: 10.1017/CBO9780511811241

Campiglio, E., 2016. Beyond carbon pricing: The role of banking and monetary policy in financing the transition to a low-carbon economy. Ecol. Econ. 121, 220–230.

Cárdenas Rodríguez, M., Haščič, I., Johnstone, N., Silva, J., Ferey, A., 2015. Renewable Energy Policies and Private Sector Investment: Evidence from Financial Microdata. Environ. Resour. Econ. 62, 163–188. https://doi.org/10.1007/s10640-014-9820-x

Carley, S., Hyman, M., 2013. The "Grand Experiment": An early review of energy-related Recovery Act efforts. Polit. Econ. Res. Inst. Work. Pap. Ser.

Chirinko, R.S., 1993. Business Fixed Investment Spending - Modeling Strategies, Empirical Results, and Policy Implications. J. Econ. Lit. 31, 1875–1911. https://doi.org/10.2307/2728330

Chu, S., Cui, Y., Liu, N., 2017. The path towards sustainable energy. Nat. Publ. Gr. 16, 16–22. https://doi.org/10.1038/nmat4834

Cullen, J.M., Allwood, J.M., 2010. Theoretical efficiency limits for energy conversion devices. Energy 35, 2059–2069. https://doi.org/10.1016/j.energy.2010.01.024

Deleidi, M., 2018. Post Keynesian endogenous money theory: A theoretical and empirical investigation of the credit demand schedule. J. Post Keynes. Econ. 41, 185–209. https://doi.org/10.1080/01603477.2017.1338967

Deleidi, M., Mazzucato, M., 2018a. The effectiveness and impact of post-2008 UK monetary policy. IIPP Policy Br. 03.

Deleidi, M., Mazzucato, M., 2018b. Putting austerity to bed: Technical progress, aggregate demand and the supermultiplier. IIPP Work. Pap. 2018–02.

Egli, F., Steffen, B., Schmidt, T.S., 2018. A dynamic analysis of financing conditions for renewable energy technologies. Nat. Energy 3. https://doi.org/10.1038/s41560-018-0277-y

Foley, D.K., Rezai, A., Taylor, L., 2013. The social cost of carbon emissions: Seven propositions. Econ. Lett. 121, 90–97.

Foray, D., Mowery, D.C., Nelson, R.R., 2012. Public R&D and social challenges: What lessons from mission R&D programs? Res. Policy 41, 1697–1702. https://doi.org/https://doi.org/10.1016/j.respol.2012.07.011

Førsund, F.R., Singh, B., Jensen, T., Larsen, C., 2008. Phasing in wind-power in Norway: Network congestion and crowding-out of hydropower. Energy Policy 36, 3514– 3520. https://doi.org/10.1016/j.enpol.2008.06.005

Freeman, C., 1995. The “National System of Innovation” in Historical Perspective. Cambridge J. Econ. 19, 5–24.

Freeman, C., Perez, C., 1988. Structural crises of adjustment, business cycles and investment behaviour, in: Dosi, G., Freeman, C., Nelson, R.R., Silverberg, G., Soete, L.L.G. (Eds.), Technical Change and Economic Theory. Pinter, London and New York, pp. 38–66.

Friedman, B.M., 1978. Crowding Out or Crowding In? Economic Consequences of Financing Government Deficits. Brookings Pap. Econ. Act. 1978, 593–654.

Friedman, M., 1968. The Role of Monetary Policy. Am. Econ. Rev. 58, 1–17.

Friedman, M., 1956. The Quantity Theory of Money: A Restatement, in: Studies in the Quantity Theory of Money. University of Chicago Press, Chicago.

Garegnani, P., 2015. The Problem of Effective Demand in Italian Economic Development: On the Factors that Determine the Volume of Investment. Rev. Polit. Econ. 27, 111–133. https://doi.org/10.1080/09538259.2015.1026096

Geddes, A., Schmidt, T.S., Steffen, B., 2018. The multiple roles of state investment banks in low-carbon energy finance: An analysis of Australia, the UK and Germany. Energy Policy 115, 158–170. https://doi.org/https://doi.org/10.1016/j.enpol.2018.01.009

Goodfriend, M., King, R.G., 1997. The New Neoclassical Synthesis and the Role of Monetary Policy, in: Bernanke, B.S., Rotemberg, J. (Eds.), NBER Macroeconomics Annual 1997. pp. 231–296.

Greenwald, B.C., Stiglitz, J.E., 1986. Externalities in Economies with Imperfect Information and Incomplete Markets. Q. J. Econ. 101, 229–264.

Grubb, M., Hourcade, J.-C., Neuhoff, K., 2014. Planetary Economics. Routledge.

Hall, B.H., Lerner, J., 2010. Chapter 14 - The Financing of R&D and Innovation, in: Hall, B.H., Rosenberg, N.B.T.-H. of the E. of I. (Eds.), Handbook of The Economics of Innovation, Vol. 1. North-Holland, pp. 609–639. https://doi.org/https://doi.org/10.1016/S0169-7218(10)01014-2

Hall, S., Foxon, T.J., Bolton, R., 2015. Investing in low-carbon transitions: energy finance as an adaptive market. Clim. Policy 1–19.

Han, C., Phillips, P.C.B., 2010. GMM ESTIMATION FOR DYNAMIC PANELS WITH FIXED EFFECTS AND STRONG INSTRUMENTS AT UNITY. Econom. Theory 26, 119–151. https://doi.org/DOI: 10.1017/S026646660909063X

Hansen, L.P., 1982. Large Sample Properties of Generalized Method of Moments

Estimators. Econometrica 50, 1029–1054. https://doi.org/10.2307/1912775

Heim, C.E., Mirowski, P., 1987. Interest Rates and Crowding-Out During Britain's Industrial Revolution. J. Econ. Hist. 47, 117–139. https://doi.org/DOI: 10.1017/S0022050700047446

IEA, 2018. World Energy Investment. International Energy Agency.

IEA, 2017. Tracking Clean Energy Progress 2017. International Energy Agency, Paris.

IMF, 2013. Greece: Ex Post Evaluation of Exceptional Access under the 2010 Stand-By Arrangement. IMF Ctry. Rep. No. 13/156.

IPCC, 2018. Global Warming of 1.5 °C.

IRENA, 2018a. Global landscape of renewable energy finance. International Renewable Energy Agency, Abu Dhabi.

IRENA, 2018b. Power Generation Costs in 2017. International Renewable Energy Agency, Abu Dhabi.

IRENA, 2017. REthinking Energy 2017: Accelerating the global energy transformation. International Renewable Energy Agency, Abu Dhabi.

Jaffe, A.B., Newell, R.G., Stavins, R.N., 2005. A tale of two market failures: Technology and environmental policy. Ecol. Econ. 54, 164–174. https://doi.org/https://doi.org/10.1016/j.ecolecon.2004.12.027

Jaiswal, A., Kwatra, S., Kaur, N., Deol, B., Weiner, E., Ghosh, A., Chawla, K., Kuldeep, N., Aggarwal, M., 2016. Greening India's Financial Market: Opportunities for a Green Bank in India. Natural Resources Defense Council & Council on Energy, Environment and Water.

Judson, R.A., Owen, A.L., 1999. Estimating dynamic panel data models : a guide for macroeconomists 65, 9–15.

Kahn, R.F., 1931. The Relation of Home Investment to Unemployment. Econ. J. 41, 173–198. https://doi.org/10.2307/2223697

Kao, C., Baltagi, B.H., 2001. Nonstationary panels, cointegration in panels and dynamic panels: A survey, in: Nonstationary Panels, Panel Cointegration, and Dynamic Panels, Advances in Econometrics. Emerald Group Publishing Limited, pp. 7–51. https://doi.org/doi:10.1016/S0731-9053(00)15002-9

Kapoor, M., Kelejian, H.H., Prucha, I.R., 2007. Panel data models with spatially correlated error components. J. Econom. 140, 97–130. https://doi.org/https://doi.org/10.1016/j.jeconom.2006.09.004

Keynes, J.M., 1936. The General Theory of Employment, Interest and Money. Macmillan, London.

Lee, L., Liu, X., 2010. EFFICIENT GMM ESTIMATION OF HIGH ORDER SPATIAL AUTOREGRESSIVE MODELS WITH AUTOREGRESSIVE DISTURBANCES. Econom. Theory 26, 187–230. https://doi.org/DOI: 10.1017/S0266466609090653

Lee, L., Yu, J., 2014. Efficient GMM estimation of spatial dynamic panel data models with fixed effects. J. Econom. 180, 174–197. https://doi.org/https://doi.org/10.1016/j.jeconom.2014.03.003

Lester, R.K., 2014. Energy innovation, in: Locke, R.M., Wellhausen, R.L. (Eds.), Production in the Innovation Economy. MIT Press, Cambridge, MA. https://doi.org/Letter

Lin, X., Lee, L., 2010. GMM estimation of spatial autoregressive models with unknown heteroskedasticity. J. Econom. 157, 34–52. https://doi.org/https://doi.org/10.1016/j.jeconom.2009.10.035

Lipsey, R.G., Lancaster, K., 1956. The General Theory of Second Best. Rev. Econ.

Stud. 24, 11. https://doi.org/10.2307/2296233

Liu, S., 2016. An Econometric Analysis of the Influence of Public Interventions on Private Investment in Climate Finance. Phd Thesis, Georgetown University.

Liu, X., Lee, L., Bollinger, C.R., 2010. An efficient GMM estimator of spatial autoregressive models. J. Econom. 159, 303–319. https://doi.org/https://doi.org/10.1016/j.jeconom.2010.08.001

Lo, K., 2014. A critical review of China's rapidly developing renewable energy and energy efficiency policies. Renew. Sustain. Energy Rev. 29, 508–516. https://doi.org/10.1016/j.rser.2013.09.006

Loftus, P.J., Cohen, A.M., Long, J.C.S., Jenkins, J.D., 2015. A critical review of global decarbonization scenarios : what do they tell us about feasibility ? WIREs Clim Chang. 6. https://doi.org/10.1002/wcc.324

Marino, M., Lhuillery, S., Parrotta, P., Sala, D., 2016. Additionality or crowding-out ? An overall evaluation of public R & D subsidy on private R & D expenditure. Res. Policy 45, 1715–1730. https://doi.org/10.1016/j.respol.2016.04.009

Mazzucato, M., 2018. The Entrepreneurial State, 2nd ed. ed. Penguin Press.

Mazzucato, M., MacFarlane, L., 2017. Patient Strategic Finance: Opportunities for State Investment Banks in the UK. Iipp Wp 2017–05, 1–79.

Mazzucato, M., Semieniuk, G., 2018. Financing renewable energy: Who is financing what and why it matters. Technol. Forecast. Soc. Change 127, 8–22. https://doi.org/10.1016/j.techfore.2017.05.021

Mazzucato, M., Semieniuk, G., 2017. Public financing of innovation: New questions. Oxford Rev. Econ. Policy 33, 24–48. https://doi.org/10.1093/oxrep/grw036

Mazzucato, M., Semieniuk, G., Geddes, A., Huang, P., Polzin, F., Gallagher, K.S., Shakya, C., Steffen, B., Tribukait, H., 2018. Bridging the gap: the role of innovation policy and market creation, in: Emissions Gap Report 2018. UNEP.

McCollum, D.L., Zhou, W., Bertram, C., de Boer, H.-S., Bosetti, V., Busch, S., Després, J., Drouet, L., Emmerling, J., Fay, M., Fricko, O., Fujimori, S., Gidden, M., Harmsen, M., Huppmann, D., Iyer, G., Krey, V., Kriegler, E., Nicolas, C., Pachauri, S., Parkinson, S., Poblete-Cazenave, M., Rafaj, P., Rao, N., Rozenberg, J., Schmitz, A., Schoepp, W., van Vuuren, D., Riahi, K., 2018. Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals. Nat. Energy 3, 589–599. https://doi.org/10.1038/s41560-018-0179-z

Mundaca, L., Richter, J.L., 2015. Assessing 'green energy economy' stimulus packages_ Evidence from the U.S. programs targeting renewable energy. Renew. Sustain. Energy Rev. 42, 1174–1186.

Nelson, R.R., 1995. Recent Evolutionary Theorizing About Economic Change. J. Econ. Lit. 33, 48–90.

Nemet, G.F., Zipperer, V., Kraus, M., 2018. The valley of death, the technology pork barrel, and public support for large demonstration projects. Energy Policy 119, 154–167. https://doi.org/https://doi.org/10.1016/j.enpol.2018.04.008

OECD, 2017. Investing in Climate, Investing in Growth. OECD Publishing, Paris.

Peden, G.C., 1984. The ``Treasury View'' on Public Works and Employment in the Interwar Period. Econ. Hist. Rev. 37, 167–181. https://doi.org/10.1111/j.1468-0289.1984.tb00324.x

Perez, C., 2002. Technological revolutions and financial capital : the dynamics of bubbles and golden ages. Edward Elgar, Cheltenham [England].

Perez, C., 1983. Structural change and assimilation of new technologies in the economic and social systems. Futures 15, 357–375.

https://doi.org/https://doi.org/10.1016/0016-3287(83)90050-2

Polzin, F., 2017. Mobilizing private finance for low-carbon innovation – A systematic review of barriers and solutions. Renew. Sustain. Energy Rev. 77, 525–535. https://doi.org/10.1016/j.rser.2017.04.007

Polzin, F., Egli, F., Steffen, B., Schmidt, T.S., 2019. How do policies mobilize private finance for renewable energy ?— A systematic review with an investor perspective. Appl. Energy 236, 1249–1268. https://doi.org/10.1016/j.apenergy.2018.11.098

Polzin, F., Migendt, M., Täube, F.A., von Flotow, P., 2015. Public policy influence on renewable energy investments—A panel data study across OECD countries. Energy Policy 80, 98–111.

Popp, D., Newell, R., 2012. Where does energy R&D come from? Examining crowding out from energy R&D. Energy Econ. 34, 980–991. https://doi.org/10.1016/j.eneco.2011.07.001

Prag, A., Röttgers, D., Scherrer, I., 2018. State-Owned Enterprises and the Low-Carbon Transition. OECD Environ. Work. Pap. No. 129. https://doi.org/10.1787/06ff826b-en

Ramey, V.A., 2011. Can Government Purchases Stimulate the Economy? J. Econ. Lit. 49, 673–685.

Robins, N., Clover, R., Singh, C., 2009. A Climate for Recovery, The colour of stimulus goes green. HSBC Global Resarch.

Sargan, J.D., 1958. The Estimation of Economic Relationships using Instrumental Variables. Econometrica 26, 393–415. https://doi.org/10.2307/1907619

Sargent, T., Lucas, R.E., 1979. After Keynesian Macroeconomics. Fed. Reserv. Bank Minneap. Q. Rev. 3, 1–18.

Schmidt, T.S., Steffen, B., Egli, F., Pahle, M., Tietjen, O., Edenhofer, O., 2019. Adverse effects of rising interest rates on sustainable energy transitions. Nat. Sustain. 2, 879–885. https://doi.org/10.1038/s41893-019-0375-2

Schumpeter, J.A., 1954. History of Economic Analysis. Oxford University Press, New York.

Semieniuk, G., 2018. Energy in Economic Growth: Is Faster Growth Greener? SOAS Dep. Econ. Work. Pap. Ser. 208.

Semieniuk, G., Mazzucato, M., 2019. Financing Green Growth, in: Handbook on Green Growth. Elgar, Cheltenham, UK.

Shrestha, R.M., Timilsina, G.R., 2002. The additionality criterion for identifying clean development mechanism projects under the Kyoto Protocol. Energy Policy 30, 73–79. https://doi.org/https://doi.org/10.1016/S0301-4215(01)00054-4

Suzumura, K., 1997. Global Aspects of Development Strategy, in: Development Strategy and Management of the Market Economy. Clarendon Press, Oxford.

Tietjen, O., Pahle, M., Fuss, S., 2016. Investment risks in power generation: A comparison of fossil fuel and renewable energy dominated markets. Energy Econ. 58, 174–185.

UNEP, BNEF, 2019. Global Trends in Renewable Energy Investment 2019. Frankfurt School of Finance & Management.

Wade, R., 1990. Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization. Princeton University Press, Princeton and Oxford.

Table 1. Variables and description

Variables	Description	Unit	Data set	Acronyms
Private asset finance/ Private investment	The private new-build financing of renewable electricity generating projects. This includes biofuel production assets.	Millions US$ at MER/year	BNEF	INV_pr
Public asset finance/ Public investment	The public new-build financing of renewable energy generating projects. This includes biofuel production assets.	Millions US$/ year	BNEF	INV_pu
Diesel tax	This indicator represents the stringency of the diesel tax.	US$/ litre	OECD	TAX_dies
Feed-in tariff for wind and solar	This indicator represents the stringency of the feed-in tariff for wind and solar energy.	US$/ KWh*	OECD	FIT_ws

Standard on emissions	An emissions standard is the maximum amount of polluting discharge legally allowed.	Environmental policy stringency Index: 0-6 in steps of 0.25	OECD	EPS_stan
GDP	Gross domestic product at constant prices (base year 2010).	Millions of national currency/ year*	OECD	GDP_real
Lending rate of interest	Lending rate of interest in percent per annum.	Percent/year	OECD	INT_lend
Energy use	Amount of primary energy consumed per person.	Kg of oil equivalent/ capita/year	WB/IEA	ENE_use
* Converted into US$ at market exchange rates.				

Table 2. Variable summary statistics converted to 2011 US$ where applicable

Variable	Unit	Mean	Median	Max	Min	SD
INV_pr	mUSD	3951.25	1966.27	31902.39	1.82	5611.27
INV_pu	mUSD	1539.93	310.53	30791.87	0.32	4394.77
TAX_dies	USD/l	0.591	0.628	1.32	0	0.372
INT_lend	%/year	3.763	1.853	44.635	-2.335	7.83
EPS_stan	0 to 6	3.853	4.5	6	0.5	1.533
ENE_use	kgoe/cap/yr	3966.555	3728.171	8441.185	441.065	2020.432
FIT_ws	USD/kWh	0.179	0.165	0.627	0	0.18
GDP_real	trn USD	3.33	2.16	17.4	0.236	4.16
INV_pr_s	mUSD	1128.121	38.41700	21371.86	0	2950.891
INV_pr_w	mUSD	1913.906	1020.260	15884.50	0	2653.158
INV_pu_s	mUSD	284.9930	3.866000	7640.092	0	1114.308
INV_pu_w	mUSD	1059.116	165.6000	23468.20	0	3408.149
FIT_s	USD/kWh	0.220280	0.116501	0.750322	0	0.241302
FIT_w	USD/kWh	0.054737	0.042430	0.275722	0	0.059252

Table 3. Initial tests

Redundant fixed effects tests (H0: fixed effects are redundant)		
Test	*Statistic*	*P-value*
Cross-section F	33.87	0.00
Cross-section Chi-square	272.66	0.00
Residual cross-section dependence test (H0: no cross-section dependence in residuals)		
Test	*Statistic*	*P-value*
Breusch-Pagan LM	162.49	0.06
Pesaran scaled LM	1.61	0.11
Pesaran CD	3.34	0.00
Panel cross-section heteroskedasticity LR test (H0: residuals are homoskedastic)		
	Statistic	*P-value*
Likelihood ratio	147.12	0.00
Panel period heteroskedasticity LR test (H0: residuals are homoskedastic)		
	Statistic	*P-value*
Likelihood ratio	9.94	0.91

Table 4. Model findings. Total RET investment

Dependent variable: private investment in INV_pr						
	FGLS		**GMM**			
	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*
INV_pu	0.21*** (0.04)	0.18*** (0.03)	0.19*** (0.02)	0.28*** (0.09)	0.28*** (0.05)	0.24*** (0.05)
TAX_dies	0.12*** (0.03)	0.07*** (0.02)	0.10*** (0.03)	0.04 (0.07)	0.00 (0.06)	-0.01 (0.04)
FIT_ws	0.16*** (0.06)	0.14*** (0.05)	0.18*** (0.06)	0.24*** (0.09)	0.25*** (0.07)	0.05 (0.09)
EPS_stan	0.01 (0.06)	-0.02 (0.06)	-0.01 (0.06)	-0.14 (0.09)	-0.08 (0.11)	0.06 (0.10)
GDP_real	0.24*** (0.08)	0.04 (0.04)	0.12*** (0.04)	0.08 (0.07)	0.01 (0.06)	0.23*** (0.08)
INT_lend	0.02 (0.05)	0.01 (0.04)	0.01 (0.03)	0.00 (0.06)	0.03 (0.07)	0.06 (0.06)
ENE_use	0.01 (0.04)	0.02 (0.04)	0.00 (0.04)	0.03 (0.09)	-0.01 (0.07)	0.02 (0.07)
$INV\_pr_{i,t-1}$	--- ---	0.23*** (0.05)	--- ---	0.21*** (0.08)	0.22*** (0.06)	-0.17*** (0.06)
C	7.23*** (0.24)	5.70*** (0.31)	7.36*** (0.23)	6.31*** (0.63)	--- ---	--- ---
n. of Observations	187	170	170	170	153	153
Durbin-Watson	1.35	1.75	1.52	1.88	---	---
J-statistic	---	---	9.42	6.54	5.68	9.16
Prob (J-statistic)	---	---	0.15	0.36	0.46	0.16

* p<0.10. ** p<0.05. *** p<0.01. Standard error in parentheses.

Table 5. Model Findings. RET investment in solar

Dependent variable: private investment in INV_pr_s						
	FGLS		**GMM**			
	Model 1_s	*Model 2_s*	*Model 3_s*	*Model 4_s*	*Model 5_s*	*Model 6_s*
INV_pu_s	1.20*** (0.14)	0.83*** (0.10)	1.19*** (0.14)	0.82*** (0.07)	0.76*** (0.17)	0.74*** (0.21)
TAX_dies	-0.07 (0.08)	0.00 (0.03)	0.00 (0.13)	0.00 (0.02)	0.13 (0.13)	0.10 (0.32)
FIT_s	0.83*** (0.08)	0.77*** (0.12)	0.84*** (0.18)	0.69*** (0.06)	0.75*** (0.16)	0.66** (0.32)
EPS_stan	0.71*** (0.10)	0.04 (0.10)	0.68*** (0.18)	-0.14 (0.27)	0.47 (0.45)	2.64 (1.97)
GDP_real	0.38*** (0.05)	0.06 (0.05)	0.39** (0.15)	0.10 (0.06)	0.20 (0.13)	0.07 (0.33)
INT_lend	0.22 (0.13)	0.06 (0.05)	0.18 (0.13)	0.04 (0.06)	0.12 (0.11)	0.20 (0.15)
ENE_use	-0.19* (0.10)	-0.05 (0.05)	-0.18 (0.13)	-0.09* (0.05)	-0.09 (0.15)	-0.02 (0.23)
$INV\_pr\_s_{i,t-1}$	--- ---	0.51*** (0.05)	--- ---	0.59*** (0.05)	0.45*** (0.15)	0.27*** (0.12)
C	0.85*** (0.24)	1.82*** (0.40)	1.03 (0.72)	2.68*** (0.97)	--- ---	--- ---
n. of Observations	187	170	170	170	153	153
Durbin-Watson	1.49	2.10	1.49	2.05	---	---
J-statistic	---	---	8.69	0.68	2.77	4.41
Prob (J-statistic)	---	---	0.19	0.99	0.74	0.49

* p<0.10. ** p<0.05. *** p<0.01. Standard error in parentheses.

Table 6. Model Findings. RET investment in wind

Dependent variable: private investment in INV_pr_w						
	FGLS		**GMM**			
	Model 1_w	*Model 2_w*	*Model 3_w*	*Model 4_w*	*Model 5_w*	*Model 6_w*
INV_pu_w	0.30*** (0.08)	0.32*** (0.08)	0.25*** (0.06)	0.32*** (0.08)	0.32*** (0.10)	0.25*** (0.10)
TAX_dies	0.09 (0.06)	0.00 (0.05)	0.08 (0.06)	0.00 (0.05)	0.00 (0.10)	0.05 (0.14)
FIT_w	0.14* (0.07)	0.28* (0.15)	0.20*** (0.06)	0.28* (0.15)	0.29** (0.13)	0.19 (0.17)
EPS_stan	0.06 (0.06)	-0.13 (0.10)	0.01 (0.08)	-0.12 (0.10)	-0.13 (0.17)	-0.05 (0.32)
GDP_real	0.18 (0.13)	-0.08 (0.16)	0.05 (0.11)	-0.08 (0.16)	-0.08 (0.14)	0.08 (0.18)
INT_lend	-0.02 (0.05)	-0.03 (0.11)	-0.06 (0.06)	-0.02 (0.11)	-0.02 (0.12)	0.04 (0.14)
ENE_use	0.21*** (0.05)	0.30** (0.15)	0.25*** (0.05)	0.31** (0.15)	0.30** (0.11)	0.19 (0.17)
$INV\_pr\_w_{i,t-1}$	--- ---	0.39*** (0.11)	--- ---	0.39*** (0.11)	0.39*** (0.08)	-0.31*** (0.10)
C	6.06*** (0.28)	4.48*** (0.91)	6.38*** (0.32)	4.48*** (0.91)	--- ---	--- ---
n. of Observations	187	170	170	170	153	153
Durbin-Watson	1.30	2.00	1.42	2.00	---	---
J-statistic	---	---	7.75	4.48	4.48	5.91
Prob (J-statistic)	---	---	0.35	0.72	0.72	0.55

* p<0.10. ** p<0.05. *** p<0.01. Standard error in parentheses.

Table 7. Arellano-Bond serial correlation test (Model 6)

Test order	*m-Statistic*	*rho*	*SE (rho)*	*P-value*
Total RE technologies investment				
AR(1)	-2.4831	-35.5337	14.3097	0.0130
AR(2)	-1.2311	-24.4031	19.8217	0.2183
RE investment in solar				
AR(1)	-3.2622	-131.3635	40.2682	0.0011
AR(2)	-1.2282	-54.0615	44.0185	0.2194
RE investment in wind				
AR(1)	-3.3934	-48.6660	14.3412	0.0007
AR(2)	-1.4047	-31.5873	22.4871	0.1601